Guidelines and Policies for Public Water Systems

Appendix N- Requirements for Microbial Toolbox Options for Meeting *Cryptosporidium* Treatment Requirements under the Long Term 2 Enhanced Surface Water Treatment Rule

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Appendix N is required by the Massachusetts Drinking Water Regulations 310CMR 22.20G
This appendix may not be modified without Deparatmental and EPA approval.

Table of Contents

INTRODUCTION

The purpose of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) is to reduce illness linked with the contaminant *Cryptosporidium* and other disease-causing microorganisms in drinking water. *Cryptosporidium* is a significant concern in drinking water because it contaminates surface waters used as drinking water sources, it is resistant to chlorine and other disinfectants, and it has caused waterborne disease outbreaks. Consuming water with *Cryptosporidium*, a contaminant in drinking water sources, can cause gastrointestinal illness, which may be severe in people with weakened immune systems (e.g., infants and the elderly) and sometimes fatal in people with severely compromised immune systems (e.g., cancer and AIDS patients).

The LT2 rule will supplement existing regulations by targeting additional *Cryptosporidium* treatment requirements for higher risk systems. The rule contains provisions to reduce risks to ensure that systems maintain microbial protection when they take steps to decrease the formation of disinfection byproducts that result from chemical water treatment.

All community and non-community surface and groundwater under the direct influence (GWIDI) systems over 10,000 are required to monitor for *Cryptosporidium* in their source water in addition to *E. coli* and turbidity. Systems under 10,000 must sample for *E. coli* and dependent on the results might have to sample for *Cryptosporidium*. The systems are placed in a bin classification following sampling based on their results. If the bin classification is greater than bin 1, that system will need additional treatment. This document provides additional information on the *Cryptosporidium* treatment to complement the Drinking Water Regulations, 310 CMR 22.20 G, Long Term 2 Enhanced Surface Water Treatment Rule (LT2).

Surface water systems required to provide treatment under the LT2 rule can select from numerous "microbial toolbox" treatment options to meet treatment requirements. This guidance manual provides additional information on the LT2 regulation and treatment requirements. It describes the 15 treatment options in the LT2ESWTR "microbial toolbox" that can be used to supplement treatment requirements under the rule.

TABLE A
CRYPTOSPORIDIUM TREATMENT COMPLIANCE DATES TABLE

Systems that serve	Must comply with *Cryptosporidium* treatment requirements no later than….*
(1) At least 100,000 people	**April 1, 2012**
(2) From 50,000 to 99,999 people	**October 1, 2012**
(3) From 10,000 to 49,999 people	**October 1, 2013**
(4) Fewer than 10,000 people	**October 1, 2014**

*** The Department may allow up to an additional two years for complying with the treatment requirement for systems making capital improvements.**

TABLE B
BIN CLASSIFICATION TABLE FOR FILTERED SYSTEMS

For Systems that are:	***Cryptosporidium* bin concentration:**	**The bin classification is:**
Required to monitor for *Cryptosporidium*	*Cryptosporidium* <0.075 oocysts/L	Bin 1
	Cryptosporidium between 0.075 and <1.0 oocysts/L	Bin 2
	Cryptosporidium between 1.0 and <3.0 oocysts/L	Bin 3
	Cryptosporidium $\geq$ 3.0 oocysts/L	Bin 4
Serving fewer than 10,000 people and NOT required to monitor for *Cryptosporidium* Under 22.20G(2)(a)4	NA	Bin 1

TABLE C
FILTERED SYSTEM ADDITIONAL *Cryptosporidium* TREATMENT REQUIREMENTS

System Bin Classification	**Type of Treatment and additional *Cryptosporidium* treatment requirements**			
	Conventional Filtration treatment	**Direct Filtration**	**Slow Sand or Diatomaceous earth filtration**	**Alternative filtration technologies**
Bin 1	No additional treatment	No additional treatment	No additional treatment	No additional treatment
Bin 2	1-log treatment	1.5-log treatment	1-log treatment	[(1)]
Bin 3	2-log treatment	2.5-log treatment	2-log treatment	[(2)]
Bin 4	2.5-log treatment	3-log treatment	2.5-log treatment	[(3)]

[1] As determined by the Department such that the total *Cryptosporidium* removal and inactivation is at least 4.0-log.
[2] As determined by the Department such that the total *Cryptosporidium* removal and inactivation is at least 5.0-log.
[3] As determined by the Department such that the total *Cryptosporidium* removal and inactivation is at least 5.5-log.

A. Microbial toolbox options for meeting *Cryptosporidium* treatment requirements.

(1). (a) Systems receive the treatment credits listed in Table D of this section by meeting the conditions for microbial toolbox options described in Appendix N, Section B – F. Systems apply these treatment credits to meet the treatment requirements in 310 CMR 22.20G(12) and (13), Filtered System Additional *Cryptosporidium* Treatment Requirement or also listed in Table C or Unfiltered System *Cryptosporidium* Treatment Requirements, as applicable.

(b) Unfiltered systems are eligible for treatment credits for the microbial toolbox options described in Section F only.

(c) The following table summarizes options in the microbial toolbox:

TABLE D

A. MICROBIAL TOOLBOX SUMMARY TABLE: OPTIONS, TREATMENT CREDITS AND CRITERIA

Toolbox Option	Log Credit	*Cryptosporidium* treatment credit with design and implementation criteria
B. Source Protection and Management Toolbox Options		
(1) Watershed control program	0.5-log	For Department-approved program comprising required elements, annual program status report to Department, and regular watershed survey. Unfiltered systems are not eligible for credit. Specific criteria are in Appendix N, B. (1).
(2) Alternative source/intake management	No prescribed credit	Systems may conduct simultaneous monitoring for treatment bin classification at alternative intake locations or under alternative intake management strategies. Specific criteria are in Appendix N, B. (2).
C. Pre Filtration Toolbox Options		
(3) Presedimentation basin with coagulation	0.5-log credit	Credit is given during any month that presedimentation basins achieve a monthly mean reduction of 0.5-log or greater in turbidity or alternative Department-approved performance criteria. To be eligible, basins must be operated continuously with coagulant addition and all plant flow must pass through basins. Specific criteria are in Appendix N, C (1).
(4) Two-stage lime softening	0.5-log credit	Credit for two-stage softening where chemical addition and hardness precipitation occur in both stages. All plant flow must pass through both stages. Single-stage softening is credited as equivalent to conventional treatment. Specific criteria are in Appendix N, C. (2).
(5) Bank filtration	0.5-log	For 25-foot setback.[1] Specific criteria are in Appendix N, C. (3).
	1.0-log	For 50-foot setback.[1] Specific criteria are in Appendix N, C. (3).
D. Treatment Performance Toolbox Options		
(6) Combined filter performance	0.5-log	Credit for combined filter effluent turbidity less than or equal to 0.15 NTU in at least 95 percent of measurements each month. Specific criteria are in Appendix N, D (1).
(7) Individual filter performance	0.5-log	Credit is given in addition to 0.5-log combined filter performance credit, credit is given if individual filter effluent

		turbidity is less than or equal to 0.15 NTU in at least 95 percent of samples each month in each filter and is never greater than 0.3 NTU in two consecutive measurements in any filter. Specific criteria are in Appendix N, D (2).
(8)Demonstration of performance	Credit awarded	Credit awarded to unit process or treatment train based on a demonstration to the Department with a Department-approved protocol. Specific criteria are in Appendix N, D (3).
E. Additional Filtration Toolbox Options		
(9) Bag or cartridge filters (individual filters)	Up to 2-log	Up to 2-log credit based on the removal efficiency demonstrated during challenge testing with a 1.0-log factor of safety. Specific criteria are in Appendix N, E (1).
(10) Bag or cartridge filters (in series)	Up to 2.5-log	Up to 2.5-log credit based on the removal efficiency demonstrated during challenge testing with a 0.5-log factor of safety. Specific criteria are in Appendix N, E (1).
(11) Membrane filtration	Log credit	Log credit equivalent to removal efficiency demonstrated in challenge test for device if supported by direct integrity testing. Specific criteria are in Appendix N, E (2).
(12) Second stage filtration	0.5-log	0.5-log credit for second separate granular media filtration stage if treatment train includes coagulation prior to first filter. Specific criteria are in Appendix N, E (3).
(13) Slow sand filters	2.5-log	Credit as a secondary filtration step.[2] Specific criteria are in Appendix N, E (4).
	3.0-log	Credit as a primary filtration process.[2] Specific criteria are in Appendix N, E (4).

F. Inactivation Toolbox Options

(14) Chlorine dioxide	CT table	Log credit based on measured CT in relation to CT table. Specific criteria in Appendix N, F (2).
(15) Ozone	CT table	Log credit based on measured CT in relation to CT table. Specific criteria in Appendix N, F (2).
(16) UV	UV dose	Log credit based on validated UV dose in relation to UV dose table; reactor validation testing required to establish UV dose and associated operating conditions. Specific criteria in Appendix N, F (4).

[1.] Aquifer must be unconsolidated sand containing at least 10 percent fines; average turbidity in wells must be less than 1 NTU. Systems using wells followed by filtration when conducting source water monitoring must sample the well to determine bin classification and are not eligible for additional credit.
[2.] No prior chlorination for either option.

B. Source toolbox components.

(1) **Watershed control program**.

Systems receive 0.5-log *Cryptosporidium* treatment credit for implementing a watershed control program that meets the requirements of this section.

(a) Systems that intend to apply for the watershed control program credit must notify the Department of this intent no later than two years prior to the treatment compliance date applicable to the system in 310CMR 22.20G(14), Schedule for Compliance with *Cryptosporidium* Treatment Requirements.

(b) Systems must submit to the Department a proposed watershed control plan no later than one year before the applicable treatment compliance date in 310 CMR 22.20G(4). The Department must approve the watershed control plan for the system to receive watershed control program treatment credit. The watershed control plan must include the following elements in this section.

(i) Identification of an "area of influence" outside of which the likelihood of *Cryptosporidium* or fecal contamination affecting the treatment plant intake is not significant. This is the area to be evaluated in future watershed surveys described below.

(ii) Identification of both potential and actual sources of *Cryptosporidium* contamination and an assessment of the relative impact of these sources on the system's source water quality.

(iii) An analysis of the effectiveness and feasibility of control measures that could reduce *Cryptosporidium* loading from sources of contamination to the system's source water.

(iv) A statement of goals and specific actions the system will undertake to reduce source water *Cryptosporidium* levels. The plan must explain how the actions are expected to contribute to specific goals, identify watershed partners and their roles, identify resource requirements and commitments, and include a schedule for plan implementation with deadlines for completing specific actions identified in the plan.

(c) Systems with existing watershed control programs (i.e., programs in place on January 5, 2006) are eligible to seek this credit. Their watershed control plans must meet the above criteria listed in B. (1)(b) of this section and must specify ongoing and future actions that will reduce source water *Cryptosporidium* levels.

(d) If the Department does not respond to a system regarding approval of a watershed control plan submitted under this section and the system meets the other requirements of this section, the watershed control program will be considered approved and 0.5 log *Cryptosporidium* treatment credit will be awarded unless and until the Department subsequently withdraws such approval.

(e) Systems must complete the following actions in paragraphs (i) through (iii) of this section to maintain the 0.5-log credit.

(i)Submit an annual watershed control program status report to the Department. The annual watershed control program status report must describe the system's implementation of the approved plan and assess the adequacy of the plan to meet its goals. It must explain how the system is addressing any shortcomings in plan implementation, including those previously identified by the Department or as the result of the watershed survey conducted under paragraph (e) (ii) of this section. It must also describe any significant changes that have occurred in the watershed since the last watershed sanitary survey. If a system determines during implementation that making a significant change to its approved watershed control program is necessary, the system must notify the Department prior to making any such changes. If any change is likely to reduce the level of source water protection, the system must also list in its notification the actions the system will take to mitigate this effect.

(ii)Undergo a watershed sanitary survey every three years for community water systems and every five years for noncommunity water systems and submit the survey report to the Department. The survey must be conducted according to Department guidelines and by persons the Department approves.

(A)The watershed sanitary survey must meet the following criteria: encompass the region identified in the Department-approved watershed control plan as the area of influence; assess the implementation of actions to reduce source water *Cryptosporidium* levels; and identify any significant new sources of Cryptosporidium.

(B)If the Department determines that significant changes may have occurred in the watershed since the previous watershed sanitary survey, systems must undergo another watershed sanitary survey by a date the Department requires, which may be earlier than the regular date in mentioned in the above paragraph (e)(ii) of this section.

(iii)The system must make the watershed control plan, annual status reports, and watershed sanitary survey reports available to the public upon request. These documents must be in a plain language style and include criteria by which to evaluate the success of the program in achieving plan goals. The Department may approve systems to withhold from the public portions of the annual status report, watershed control plan, and watershed sanitary survey based on water supply security considerations.

(f)If the Department determines that a system is not carrying out the approved watershed control plan, the Department may withdraw the watershed control program treatment credit.

(2) **<u>Alternative source</u>**.

(a) A system may conduct source water monitoring that reflects a different intake location (either in the same source or for an alternate source) or a different procedure for the timing or level of withdrawal from the source (alternative source monitoring). If the Department approves, a system may determine its bin classification under 310 CMR 22.20G(11), Bin Classification for Filtered Systems and Table B in Appendix N, based on the alternative source monitoring results.

(b) If systems conduct alternative source monitoring under this section, systems must also monitor their current plant intake concurrently as described in 310 CMR 22.20G(2), Source Water Monitoring.

(c) Alternative source monitoring under this section must meet the requirements for source monitoring to determine bin classification, as described in 310 CMR 22.20G (2) through (7), Source Water Monitoring Requirements. Systems must report the alternative source monitoring results to the Department, along with supporting information documenting the operating conditions under which the samples were collected.

(d) If a system determines its bin classification under 310 CMR 22.20G (11), Bin Classification for Filtered Systems or Table B in Appendix N, using alternative source monitoring results that reflect a different intake location or a different procedure for managing the timing or level of withdrawal from the source, the system must relocate the intake or permanently adopt the withdrawal procedure, as applicable, no later than the applicable treatment compliance date in 310 CMR 22.20G(14), Schedule for Compliance with *Cryptosporidium* Treatment Requirements and Table A in Appendix N.

C. **Pre-filtration treatment toolbox components**.

(1) Presedimentation. Systems receive 0.5-log *Cryptosporidium* treatment credit for a presedimentation basin during any month the process meets the following criteria in this paragraph.

(a) The presedimentation basin must be in continuous operation and must treat the entire plant flow taken from a surface water source or a ground water source under the direct influence of surface water (GWUDI) source.

(b) The system must continuously add a coagulant to the presedimentation basin.

(c) The presedimentation basin must achieve the following performance criteria in C.(1) (c)(i) or (ii) of this section.

(i) Demonstrates at least 0.5-log mean reduction of influent turbidity. This reduction must be determined using daily turbidity measurements in the presedimentation process influent and effluent and must be calculated as follows: $\log_{10}$ (monthly mean of daily influent turbidity) - $\log_{10}$ (monthly mean of daily effluent turbidity).

(ii)Complies with Department-approved performance criteria that demonstrate at least 0.5-log mean removal of micron-sized particulate material through the presedimentation process.

(2) Two-stage lime softening. Systems receive an additional 0.5-log *Cryptosporidium* treatment credit for a two-stage lime softening plant if chemical addition and hardness precipitation occur in two separate and sequential softening stages prior to filtration. Both softening stages must treat the entire plant flow taken from a surface water source or a ground water source under the direct influence of surface water (GWUDI) source.

(3) Bank filtration. Systems receive *Cryptosporidium* treatment credit for bank filtration that serves as pretreatment to a filtration plant by meeting the criteria in this paragraph. Systems using bank filtration when they begin source water monitoring under 310 CMR 22.20G(2)(a), Source Water Monitoring, must collect samples as described in 310 CMR 22.20G(4)(d), Sampling Locations, and are not eligible for this credit.

(a) Wells with a ground water flow path of at least 25 feet receive 0.5-log treatment credit; wells with a groundwater flow path of at least 50 feet receive 1.0-log treatment credit. The ground water flow path must be determined as specified in the following paragraph (d) of this section.

(b) Only wells in granular aquifers are eligible for treatment credit. Granular aquifers are those comprised of sand, clay, silt, rock fragments, pebbles or larger particles, and minor cement. A system must characterize the aquifer at the well site to determine aquifer properties. Systems must extract a core from the aquifer and demonstrate that in at least 90 percent of the core length, grains less than 1.0 mm in diameter constitute at least 10 percent of the core material.

(c) Only horizontal and vertical wells are eligible for treatment credit.

(d) For vertical wells, the groundwater flow path is the measured distance from the edge of the surface water body under high flow conditions (determined by the 100 year floodplain elevation boundary or by the floodway, as defined in Federal Emergency Management Agency flood hazard maps) to the well screen. For horizontal wells, the ground water flow path is the measured distance from the bed of the river under normal flow conditions to the closest horizontal well lateral screen.

(e) Systems must monitor each wellhead for turbidity at least once every four hours while the bank filtration process is in operation. If monthly average turbidity levels, based on daily maximum values in the well, exceed 1 NTU, the system must report this result to the Department and conduct an assessment within 30 days to determine the cause of the high turbidity levels in the well. If the Department determines that microbial removal has been compromised, the Department may revoke treatment credit until the system implements corrective actions approved by the Department to remediate the problem.

(f) Springs and infiltration galleries are not eligible for treatment credit under bank filtration credit, but are eligible for credit under Appendix N, D.(3), Demonstration of Performance.

(g) Bank filtration demonstration of performance. The Department may approve *Cryptosporidium* treatment credit for bank filtration based on a demonstration of performance study that meets the criteria in this paragraph. This treatment credit may be greater than 1.0-log and may be awarded to bank filtration that does not meet the criteria in the following paragraphs.

(i) The study must follow a Department-approved protocol and must involve the collection of data on the removal of *Cryptosporidium* or a surrogate for *Cryptosporidium* and related hydrogeologic and water quality parameters during the full range of operating conditions.

(ii) The study must include sampling both from the production well(s) and from monitoring wells that are screened and located along the shortest flow path between the surface water source and the production well(s).

D. **Treatment performance toolbox components.**

(1) <u>Combined filter performance</u>.

Systems using conventional filtration treatment or direct filtration treatment receive an additional 0.5-log *Cryptosporidium* treatment credit during any month the system meets the criteria in this paragraph. Combined filter effluent (CFE) turbidity must be less than or equal to 0.15 NTU in at least 95 percent of the measurements. Turbidity must be measured as described in 310 CMR 22.20A(5)(a) and (c).

(2) <u>Individual filter performance.</u>

Systems using conventional filtration treatment or direct filtration treatment receive 0.5-log Cryptosporidium treatment credit, which can be in addition to the combined filter performance 0.5-log credit described under paragraph (1) of this section, during any month the system meets the criteria in this paragraph. Compliance with these criteria must be based on individual filter turbidity monitoring as described in 310 CMR 22.20A(5) or 22.20D as applicable.

(a) The filtered water turbidity for each individual filter must be less than or equal to 0.15 NTU in at least 95 percent of the measurements recorded each month.

(b) No individual filter may have a measured turbidity greater than 0.3 NTU in two consecutive measurements taken15 minutes apart.

(c) Any system that has received treatment credit for individual filter performance and fails to meet the requirements of D.(2)(a) and (b) of this section during any month does not receive a treatment technique violation under 310 CMR 22.20G(12)(c), Filtered System Additional *Cryptosporidium* Treatment Requirements, if the Department determines the following:

(i) The failure was due to unusual and short-term circumstances that could not reasonably be prevented through optimizing treatment plant design, operation and maintenance.

(ii)The system has experienced no more than two such failures in any calendar year.

(3) Demonstration of performance.

The Department may approve *Cryptosporidium* treatment credit for drinking water treatment processes based on a demonstration of performance study that meets the criteria in this paragraph. This treatment credit may be greater than or less than the prescribed treatment credits in 310 CMR 22.20G(12), Filtered System Additional *Cryptosporidium* Treatment Requirements, or Appendix N, Sections C through F and may be awarded to treatment processes that do not meet the criteria for the prescribed credits.

(a) Systems cannot receive the prescribed treatment credit for any toolbox option in Appendix N, Sections C through F if that toolbox option is included in a demonstration of performance study for which treatment credit is awarded under this section.

(b) The demonstration of performance study must follow a Department-approved protocol and must demonstrate the level of *Cryptosporidium* reduction the treatment process will achieve under the full range of expected operating conditions for the system.

(c) Approval by the Department must be in writing and may include monitoring and treatment performance criteria that the system must demonstrate and report on an ongoing basis to remain eligible for the treatment credit. The Department may designate such criteria where necessary to verify that the conditions under which the demonstration of performance credit was approved are maintained during routine operation.

E. **Additional filtration toolbox components.**

(1) Bag and cartridge filters. Systems receive *Cryptosporidium* treatment credit of up to 2.0-log for individual bag or cartridge filters and up to 2.5-log for bag or cartridge filters operated in series by meeting the criteria in sections (a) through (j) of this section. To be eligible for this credit, systems must report the results of challenge testing that meets the requirements of paragraphs (a) through (i) of this section to the Department. The filters must treat the entire plant flow taken from a surface water source or ground water source under the direct influence of surface water (GWUDI) source.

(a) The *Cryptosporidium* treatment credit awarded to bag or cartridge filters must be based on the removal efficiency demonstrated during challenge testing that is conducted according to the criteria in paragraphs (a) through (i) of this section. A factor of safety equal to 1-log for individual bag or cartridge filters and 0.5-log for bag or cartridge filters in series must be applied to challenge testing results to determine removal credit. Systems may use results from challenge testing conducted prior to January 5, 2006 if the prior testing was consistent with the criteria specified in E. (1) (a) through (i) of this section.

(b) Challenge testing must be performed on full-scale bag or cartridge filters, and the associated filter housing or pressure vessel, that are identical in material and construction to the filters and housings the system will use for removal of *Cryptosporidium*. Bag or cartridge filters must be challenge tested in the same configuration that the system will use, either as individual filters or as a series configuration of filters.
(c) Challenge testing must be conducted using *Cryptosporidium* or a surrogate that is removed no more efficiently than *Cryptosporidium*. The microorganism or surrogate used during challenge testing is referred to as the challenge particulate. The concentration of the challenge particulate must be determined using a method capable of discreetly quantifying the specific microorganism or surrogate used in the test; gross measurements such as turbidity may not be used.
(d) The maximum feed water concentration that can be used during a challenge test must be based on the detection limit of the challenge particulate in the filtrate (i.e., filtrate detection limit) and must be calculated using the following equation:
Maximum Feed Concentration $=1 \times 10^4 \times$ (Filtrate Detection Limit)
(e) Challenge testing must be conducted at the maximum design flow rate for the filter as specified by the manufacturer.
(f) Each filter evaluated must be tested for duration sufficient to reach 100 percent of the terminal pressure drop, which establishes the maximum pressure drop under which the filter may be used to comply with the requirements of E. (1) of this section.
(g) Removal efficiency of a filter must be determined from the results of the challenge test and expressed in terms of log removal values using the following equation:
$LRV = LOG_{10}(C_f) - LOG_{10}(C_p)$
Where:
LRV =log removal value demonstrated during challenge testing;C_f = the feed concentration measured during the challenge test; and C_p =the filtrate concentration measured during the challenge test. In applying this equation, the same units must be used for the feed and filtrate concentrations. If the challenge particulate is not detected in the filtrate, then the term C_p must be set equal to the detection limit.
(h) Each filter tested must be challenged with the challenge particulate during three periods over the filtration cycle: within two hours of start-up of a new filter; when the pressure drop is between 45 and 55 percent of the terminal pressure drop; and at the end of the cycle after the pressure drop has reached 100 percent of the terminal pressure drop. An LRV must be calculated for each of these challenge periods for each filter tested. The LRV for the filter (LRV_{filter}) must be assigned the value of the minimum LRV observed during the three challenge periods for that filter.
(i) If fewer than 20 filters are tested, the overall removal efficiency for the filter product line must be set equal to the lowest LRV_{filter} among the filters tested. If 20 or more filters are tested, the overall removal efficiency for the filter product line must be set equal to the 10th percentile of the set of LRV_{filter} values for the various filters tested. The percentile is defined by (i/(n+1)) where i is the rank of n individual data points ordered lowest to highest. If necessary, the 10th percentile may be calculated using linear interpolation.

(j) If a previously tested filter is modified in a manner that could change the removal efficiency of the filter product line, challenge testing to demonstrate the removal efficiency of the modified filter must be conducted and submitted to the Department.

(2) Membrane filtration.

(a) Systems receive *Cryptosporidium* treatment credit for membrane filtration that meets the criteria of this paragraph. Membrane cartridge filters that meet the definition of membrane filtration in 310 CMR 22.02, Definitions, are eligible for this credit. The level of treatment credit a system receives is equal to the lower of the values determined in sections (i) and (ii).

(i) The removal efficiency demonstrated during challenge testing conducted under the conditions in (2) (b) of this section.

(ii) The maximum removal efficiency that can be verified through direct integrity testing used with the membrane filtration process under the conditions in (2) (c) of this section.

(b) *Challenge Testing.* The membrane used by the system must undergo challenge testing to evaluate removal efficiency and the system must report the results of challenge testing to the Department. Challenge testing must be conducted according to the criteria in (2)(b) (i) through (vii) of this section. Systems may use data from challenge testing conducted prior to January 5, 2006 if the prior testing was consistent with the criteria in (2) (b) (i) through (vii) of this section.

(i) Challenge testing must be conducted on either a full-scale membrane module, identical in material and construction to the membrane modules used in the system's treatment facility, or a smaller-scale membrane module, identical in material and similar in construction to the full-scale module. A module is defined as the smallest component of a membrane unit in which a specific membrane surface area is housed in a device with a filtrate outlet structure.

(ii) Challenge testing must be conducted using *Cryptosporidium* oocysts or a surrogate that is removed no more efficiently than *Cryptosporidium* oocysts. The organism or surrogate used during challenge testing is referred to as the challenge particulate. The concentration of the challenge particulate, in both the feed and filtrate water, must be determined using a method capable of discretely quantifying the specific challenge particulate used in the test; gross measurements such as turbidity may not be used.

(iii) The maximum feed water concentration that can be used during a challenge test is based on the detection limit of the challenge particulate in the filtrate and must be determined according to the following equation:

Maximum Feed Concentration $= 3.16 \times 10^6 \times$ (Filtrate Detection Limit)

(iv) Challenge testing must be conducted under representative hydraulic conditions at the maximum design flux and maximum design process recovery specified by the manufacturer for the membrane module. Flux is defined as the throughput of a pressure driven membrane process expressed as flow per unit of membrane area. Recovery is defined as the volumetric percent of feed water that is converted to filtrate over the course of an operating cycle uninterrupted by events such as chemical cleaning or a solids removal process (*i.e.*, backwashing).

(v) Removal efficiency of a membrane module must be calculated from the challenge test results and expressed as a log removal value according to the following equation:

$LRV = LOG_{10}(C_f) - LOG_{10}(C_p)$

Where:

LRV =log removal value demonstrated during the challenge test; C_f =the feed concentration measured during the challenge test; and C_p =the filtrate concentration measured during the challenge test. Equivalent units must be used for the feed and filtrate concentrations. If the challenge particulate is not detected in the filtrate, the term C_p is set equal to the detection limit for the purpose of calculating the LRV. An LRV must be calculated for each membrane module evaluated during the challenge test.

(vi)The removal efficiency of a membrane filtration process demonstrated during challenge testing must be expressed as a log removal value ($LRV_{c\text{-}Test}$). If fewer than 20 modules are tested, then $LRV_{c\text{-}Test}$ is equal to the lowest of the representative LRVs among the modules tested. If 20 or more modules are tested, then $LRV_{c\text{-}Test}$ is equal to the 10th percentile of the representative LRVs among the modules tested. The percentile is defined by (i/ (n+1)) where i is the rank of n individual data points ordered lowest to highest. If necessary, the 10th percentile may be calculated using linear interpolation.

(vii) The challenge test must establish a quality control release value (QCRV) for a non-destructive performance test that demonstrates the *Cryptosporidium* removal capability of the membrane filtration module. This performance test must be applied to each production membrane module used by the system that was not directly challenge tested in order to verify *Cryptosporidium* removal capability. Production modules that do not meet the established QCRV are not eligible for the treatment credit demonstrated during the challenge test.

(viii) If a previously tested membrane is modified in a manner that could change the removal efficiency of the membrane or the applicability of the non-destructive performance test and associated QCRV, additional challenge testing to demonstrate the removal efficiency of, and determine a new QCRV for, the modified membrane must be conducted and submitted to the Department.

(c) *Direct integrity testing.* Systems must conduct direct integrity testing in a manner that demonstrates a removal efficiency equal to or greater than the removal credit awarded to the membrane filtration process and meets the requirements described in (2) (c)(i) through (vi) of this section. A direct integrity test is defined as a physical test applied to a membrane unit in order to identify and isolate integrity breaches (*i.e.*, one or more leaks that could result in contamination of the filtrate).

(i) The direct integrity test must be independently applied to each membrane unit in service. A membrane unit is defined as a group of membrane modules that share common valving that allows the unit to be isolated from the rest of the system for the purpose of integrity testing or other maintenance.

(ii) The direct integrity method must have a resolution of 3 micrometers or less, where resolution is defined as the size of the smallest integrity breach that contributes to a response from the direct integrity test.

(iii) The direct integrity test must have sensitivity sufficient to verify the log treatment credit awarded to the membrane filtration process by the Department, where sensitivity is defined as the maximum log removal value that can be reliably verified by a direct integrity test. Sensitivity must be determined using the approach in either (2)(c)(iii) (A) or (B) of this section as applicable to the type of direct integrity test the system uses.

(A) For direct integrity tests that use an applied pressure or vacuum, the direct integrity test sensitivity must be calculated according to the following equation:

$LRV_{DIT} = LOG_{10}(Q_p / (VCF \times Q_{breach}))$

Where:

LRV_{DIT} =the sensitivity of the direct integrity test; Q_p =total design filtrate flow from the membrane unit; Q_{breach} =flow of water from an integrity breach associated with the smallest integrity test response that can be reliably measured, and VCF=volumetric concentration factor. The volumetric concentration factor is the ratio of the suspended solids concentration on the high pressure side of the membrane relative to that in the feed water.

(B) For direct integrity tests that use a particulate or molecular marker, the direct integrity test sensitivity must be calculated according to the following equation:

$LRV_{DIT} = LOG_{10}(C_f) - LOG_{10}(C_p)$

Where:

LRV_{DIT} =the sensitivity of the direct integrity test; C_f =the typical feed concentration of the marker used in the test; and C_p =the filtrate concentration of the marker from an integral membrane unit.

(iv) Systems must establish a control limit within the sensitivity limits of the direct integrity test that is indicative of an integral membrane unit capable of meeting the removal credit awarded by the Department.

(v) If the result of a direct integrity test exceeds the control limit established under (2)(c) (iv) of this section, the system must remove the membrane unit from service. Systems must conduct a direct integrity test to verify any repairs, and may return the membrane unit to service only if the direct integrity test is within the established control limit.

(vi) Systems must conduct direct integrity testing on each membrane unit at a frequency of not less than once each day that the membrane unit is in operation. The Department may approve less frequent testing, based on demonstrated process reliability, the use of multiple barriers effective for *Cryptosporidium*, or reliable process safeguards.

(d) *Indirect integrity monitoring.*

Systems must conduct continuous indirect integrity monitoring on each membrane unit according to the criteria in (2)(d)(i) through (v) of this section. Indirect integrity monitoring is defined as monitoring some aspect of filtrate water quality that is indicative of the removal of particulate matter. A system that implements continuous direct integrity testing of membrane units in accordance with the criteria in (2)(c)(i) through (v) of this section is not subject to the requirements for continuous indirect integrity monitoring. Systems must submit a monthly report to the Department summarizing all continuous indirect integrity monitoring results triggering direct integrity testing and the corrective action that was taken in each case.

(i) Unless the Department approves an alternative parameter, continuous indirect integrity monitoring must include continuous filtrate turbidity monitoring.

(ii) Continuous monitoring must be conducted at a frequency of no less than once every 15 minutes.

(iii) Continuous monitoring must be separately conducted on each membrane unit.

(iv) If indirect integrity monitoring includes turbidity and if the filtrate turbidity readings are above 0.15 NTU for a period greater than 15 minutes (i.e., two consecutive 15-minute readings above 0.15 NTU), direct integrity testing must immediately be performed on the associated membrane unit as specified in (2)(d)(i) through (v) of this section.

(v) If indirect integrity monitoring includes a Department-approved alternative parameter and if the alternative parameter exceeds a Department-approved control limit for a period greater than 15 minutes, direct integrity testing must immediately be performed on the associated membrane units as specified in (2)(c)(i) through (v) of this section.

(3) Second stage filtration. Systems receive 0.5-log *Cryptosporidium* treatment credit for a separate second stage of filtration that consists of sand, dual media, GAC, or other fine grain media following granular media filtration if the Department approves. To be eligible for this credit, the first stage of filtration must be preceded by a coagulation step and both filtration stages must treat the entire plant flow taken from a surface water source or ground water source under the direct influence of surface water (GWUDI) source. A cap, such as GAC, on a single stage of filtration is not eligible for this credit. The Department must approve the treatment credit based on an assessment of the design characteristics of the filtration process.

(4) Slow sand filtration *(as secondary filter).* Systems are eligible to receive 2.5-log *Cryptosporidium* treatment credit for a slow sand filtration process that follows a separate stage of filtration if both filtration stages treat the entire plant flow taken from a surface water source or ground water source under the direct influence of surface water and no disinfectant residual is present in the influent water to the slow sand filtration process. The Department must approve the treatment credit based on an assessment of the design characteristics of the filtration process. This paragraph does not apply to treatment credit awarded to slow sand filtration used as a primary filtration process.

F. Inactivation toolbox components.

(1) Calculation of CT values.

(a) CT is the product of the disinfectant contact time (T, in minutes) and disinfectant concentration (C, in milligrams per liter). Systems with treatment credit for chlorine dioxide or ozone under F (2) or (3) of this section must calculate CT at least once each day, with both C and T measured during peak hourly flow as specified in 310 CMR 22.20A(5)(a) and (b).

(b) Systems with several disinfection segments in sequence may calculate CT for each segment, where a disinfection segment is defined as a treatment unit process with a measurable disinfectant residual level and a liquid volume. Under this approach, systems must add the *Cryptosporidium* CT values in each segment to determine the total CT for the treatment plant.

(2) <u>CT values for chlorine dioxide and ozone</u>

(a) Systems receive the *Cryptosporidium* treatment credit listed in Appendix N, Table E by meeting the corresponding chlorine dioxide CT value for the applicable water temperature, as described in F (1) of this section.

TABLE E
CT VALUES (MG ·MIN/L) FOR *Cryptosporidium* INACTIVATION BY CHLORINE DIOXIDE [1]

Log credit	Water Temperature, ºC										
	<=0.5	1	2	3	5	7	10	15	20	25	30
0.25	159	153	140	128	107	90	69	45	29	19	12
0.5	319	305	279	256	214	180	138	89	58	38	24
1.0	637	610	558	511	429	360	277	179	116	75	49
1.5	956	915	838	767	643	539	415	268	174	113	73
2.0	1275	1220	1117	1023	858	719	553	357	232	150	98
2.5	1594	1525	1396	1278	1072	899	691	447	289	188	122
3.0	1912	1830	1675	1534	1286	1079	830	536	347	226	147

[1] Systems may use this equation to determine log credit between the indicated values: Log credit = $(0.001506 \times (1.09116)^{Temp}) \times CT$.

(b) Systems receive the *Cryptosporidium* treatment credit listed in Table F by meeting the corresponding ozone CT values for the applicable water temperature, as described in F.(1) of this section.

TABLE F
CT VALUES (MG·MIN/L) FOR *Cryptosporidium* INACTIVATION BY OZONE [1]

Log Credit	Water Temperature, º C										
	<=0.5	1	2	3	5	7	10	15	20	25	30
0.25	6.0	5.8	5.2	4.8	4.0	3.3	2.5	1.6	1.0	0.6	0.39
0.5	12	12	10	9.5	7.9	6.5	4.9	3.1	2.0	1.2	0.78
1.0	24	23	21	19	16	13	9.9	6.2	3.9	2.5	1.6
1.5	36	35	31	29	24	20	15	9.3	5.9	3.7	2.4
2.0	48	46	42	38	32	26	20	12	7.8	4.9	3.1
2.5	60	58	52	48	40	33	25	16	9.8	6.2	3.9
3.0	72	69	63	57	47	39	30	19	12	7.4	4.7

[1] Systems may use this equation to determine log credit between the indicated values: Log credit = $(0.0397 \times (1.09757)^{Temp}) \times CT$.

(3)Site-specific study. The Department may approve alternative chlorine dioxide or ozone CT values to those listed in Table E or F of this section on a site-specific basis. The Department must base this approval on a site-specific study a system conducts that follows a Department-approved protocol.

(4) Ultraviolet light Systems receive *Cryptosporidium*, *Giardia lamblia*, and virus treatment credits for ultraviolet (UV) light reactors by achieving the corresponding UV dose values shown in Table G of this section. Systems must validate and monitor UV reactors as described in F. (4)(b) and (c) of this section to demonstrate that they are achieving a particular UV dose value for treatment credit.

(a) *UV dose table*. The treatment credits listed in this table are for UV light at a wavelength of 254 nm as produced by a low pressure mercury vapor lamp. To receive treatment credit for other lamp types, systems must demonstrate an equivalent germicidal dose through reactor validation testing, as described in F.(4)(b) of this section. The UV dose values in this table are applicable only to post-filter applications of UV in filtered systems and to unfiltered systems.

TABLE G
UV DOSE TABLE FOR *Cryptosporidium*, *Giardia lamblia*, and VIRUS INACTIVATION CREDIT

Log credit	*Cryptosporidium* UV dose (mJ/cm^2)	*Giardia lamblia* UV dose (mJ/cm^2)	Virus UV dose (mJ/cm^2)
0.5	1.6	1.5	39
1.0	2.5	2.1	58
1.5	3.9	3.0	79
2.0	5.8	5.2	100
2.5	8.5	7.7	121
3.0	12	11	143
3.5	15	15	163
4.0	22	22	186

(b) *Reactor validation testing*. Systems must use UV reactors that have undergone validation testing to determine the operating conditions under which the reactor delivers the UVdose required in F.(4) (a) of this section (*i.e.*, validated operating conditions).These operating conditions must include flow rate, UV intensity as measured by a UV sensor, and UV lamp status.

(i) When determining validated operating conditions, systems must account for the following factors:UV absorbance of the water; lamp fouling and aging; measurement uncertainty of on-line sensors; UV dose distributions arising from the velocity profiles through the reactor; failure of UV lamps or other critical system components; and inlet and outlet piping or channel configurations of the UV reactor.

(ii) Validation testing must include the following: Full scale testing of a reactor that conforms uniformly to the UV reactors used by the system and inactivation of a test microorganism whose dose response characteristics identified with a low pressure mercury vapor lamp.

(iii) The Department may approve an alternative approach to validation testing.

(c) *Reactor monitoring.*

(i) Systems must monitor their UV reactors to determine if the reactors are operating within validated conditions, as determined under F. (4)(b) of this section. This monitoring must include UV intensity as measured by a UV sensor, flow rate, lamp status, and other parameters the Department designates as based on UV reactor operation. Systems must verify the calibration of UV sensors and must recalibrate sensors in accordance with a protocol the Department approves.

(ii) To receive treatment credit for UV light, systems must treat at least 95 percent of the water delivered to the public during each month by UV reactors operating within validated conditions for the required UV dose, as described in F.(4)(a) and (b) of this section. Systems must demonstrate compliance with this condition by the monitoring required under F.(4)(c)(i) of this section.

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